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Freight network design with logistics operation management

Camille Gras^{1,2}, Van-Dat Cung¹, Nathalie Herr², Alantha Newman¹, Nicolas Teypaz²

¹ Univ. Grenoble Alpes, CNRS, Grenoble INP † G-SCOP, 38000 Grenoble, France

{van-dat.cung,camille.gras,alantha.newman}@grenoble-inp.fr

² ProbaYes, 38 330, Montbonnot, France

{camille.gras,nathalie.herr,nicolas.teypaz}@probayes.com

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1 Introduction

This work deals with a parcels delivery problem and its extension to other freight transport problems. It is a sub-case of the well-known Service Network Design with Asset Management problem (SNDAM). Parcels delivery has been studied by several authors like Zäpfel and Wasner [3] who optimized the parcels delivery network in Austria (10 depots and one hub) thanks to integer programming. To build the right model, they studied different type of networks. They showed that a pure hub-and-spoke network is not optimal and studied the interest of using direct paths between gathering points and dispersion points in regards to a pure hub-and-spoke network. They stated that an hybrid hub-and-spoke network is optimal in their case.

In bigger countries, the number of sites (ports, airports, warehouses, ...) does not allow a direct use of linear programming. That's why Barnhart [1] optimized the express shipment delivery network in the USA with a heuristic. She divided the service network design problem into two subproblems : route generation and shipment movement. She solved each one of these problems and iterated. This heuristic which could be seen as a route-and-flow-generation algorithm is pretty interesting when demands cannot be divided and shipped on different paths.

More generally, the SNDAM problem has been studied by Chouman and Crainic[2] : the Cut&Fix matheuristic. They say that for small data instances an exact solving with a MILP is the best option, they propose this matheuristic to optimize big data instances. It consists in identifying promising variables thanks to learning mechanisms embedded into a cutting-plane procedure in order to fix this variables and reduce the dimension of the problem instance and therefore make it addressable by a MILP solver. However, this problem is more general and it does not takes into account some specificities of the parcels delivery problem.

2 The considered parcels delivery problem

The problem tackled here consists in finding an optimal routing for parcels while delivering all the parcels sent from and towards all the sites in France. The sites locations are known and the service network and the routing have to be decided while minimizing the monetary and time costs. The routing is made for one day, for a given set of demands (Origine-Destination-Demand triples). We consider that the demand forecast is known since it is a distinct problem.

The sites are of two types : origin and destination. The origin sites are the only sites which can be used as intermediate sites. Between the origin and the destination sites, up to two sites can be crossed. All the sites can be linked as the network is complete. Between two sites, the parcels are transported in containers. A container carries parcels for one destination (intermediate or final). It cannot carry parcels for various destinations and be partially emptied

[†]Institute of Engineering Univ. Grenoble Alpes

like in VRP. That is why parcels have to be sorted and sent in distinct containers towards their destinations. In this optimization process, the path of each container in the transport network has to be determined, as well as the treatment of parcels in each site.

A first sorting is done in the gathering place to group the parcels according to their final destination. After that, one or two sorting can be done on intermediate sites before sending the parcels to their final destination. Two other operations can be done during the ride : (1) the containers can swap vehicles as one vehicle can carry one or two containers (container swapping) and (2) the containers can be completed in intermediate sites (co-loading). Finally, the trucks and containers balance has to be managed. Therefore this problem belongs to the family of SNDAM problems and more precisely it is an Origin-Destination Service Network Design with Asset Management problem. It is challenging as it tackles the the three levels of decision-making of transport planning, namely the strategic level, the tactical level and the operational level.

As the number of possible operations and crossed sites combinations for each parcels is bounded, we set up a path-oriented MILP for our problem and solved it with a MILP solver (CPLEX 12.7). However, the MILP did not reach the optimal solution for a complete data instance (14 origin sites and 140 destination sites) in reasonable time (no interesting solution after 24h computing). But it did reach a better solution than the current one in less than 1h for a data instance which represents around 36% of the demands with 14 origin sites and 124 destination sites (83% of the sites). To have a solution for the complete data instance we did a preselection of our variables : we removed from the model some variables we considered as bad paths unlikely to be chosen. It reduced the number of possible paths of our network so it became small enough to be solved. It allowed us to have optimal solutions for the reduced model in less than 10 minutes. Yet to reach this speed of execution we had to remove the swapping and co-loading operations.

We also developed a heuristic. It consists in fixing some good paths for each demand (based on a size criterion). Then this solution is injected as a starting point in the resolution by the MILP solver. It allows to have quickly a small gap in the problem with all the operations but it does not reach a very small gap for the complete data instance. The solutions obtained are very good in term of money saved with the new solution with regards to the current one but not optimal.

3 Conclusion and perspectives

We studied a SNDAM problem through the case of parcel delivery. A MILP has been proposed to model the problem and its solving using CPLEX helped us to better understand the specificities of this problem and provided very good solutions. Yet we did not considered all the possible operations so this would be our first perspective.

In a broader perspective, we want to extend the optimization methods for parcels delivery problem to other freight transport problems. These problems occur in various business sectors like air or maritime freight, or passenger transportation.

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